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(71), (72) and (74) continued overleaf

(54) Multiphase cross-correlation flowmeter

(57) A flowmeter for measuring the flow rates of individual phases of a multiphase flow comprises two capacitive sensors 21,31 consisting of electrodes 21a,21b,31a,31b attached to a conduit 10 through which the fluid under test flows. The sensors are spaced a known distance L apart along the conduit and the sensor signals are cross-correlated (40) to determine flow speed, the speed signals being used in a flow rate calculating circuit 50 to give a measure of flow rate. Signals relating to individual phases are provided by operating the sensors at various different frequencies, making use of the fact that the dielectric constants of the various phases alter with frequency in different ways (see figure 3).

F I G. 1

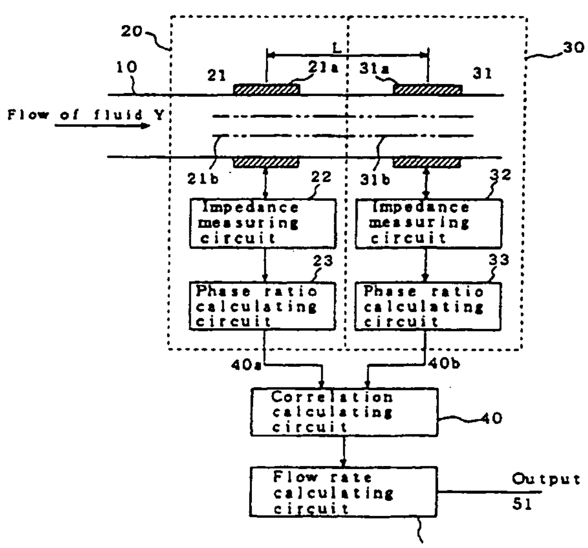

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FIG. 1

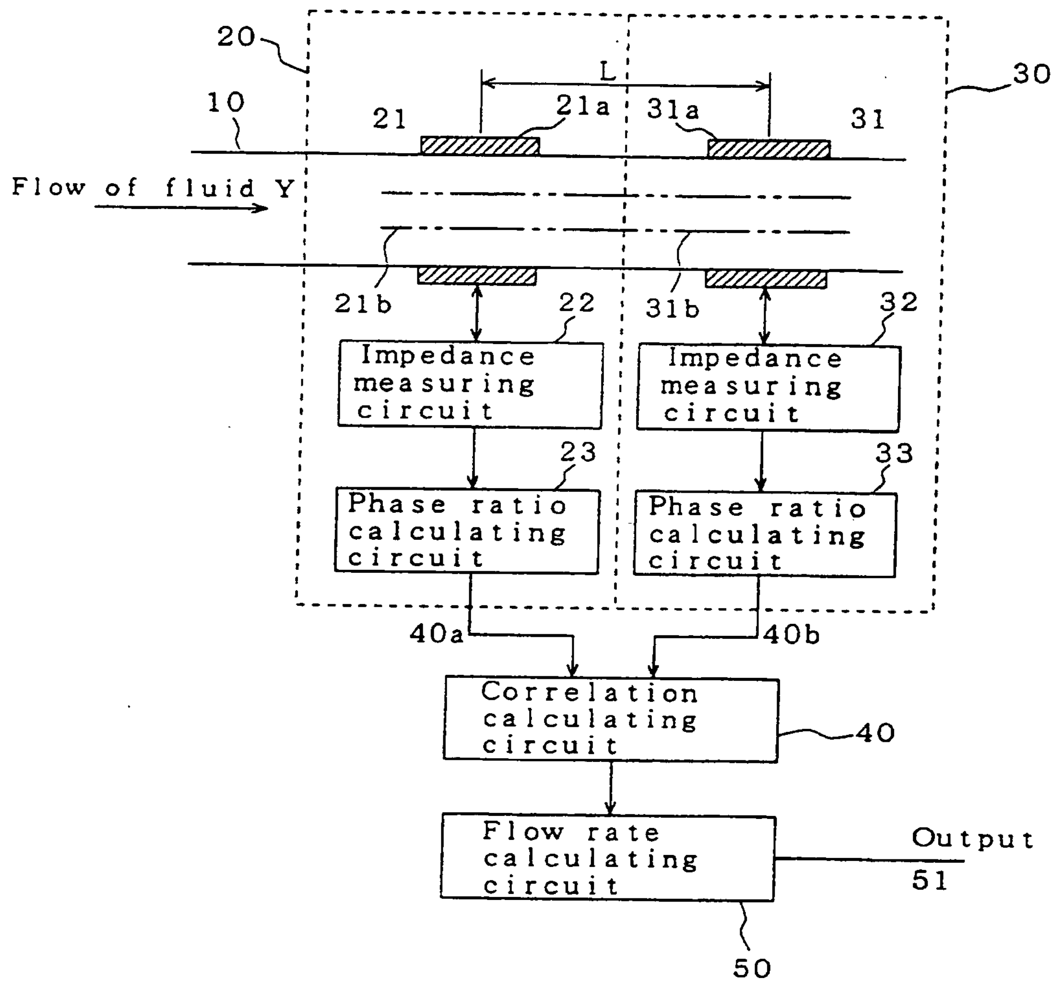


FIG. 2A

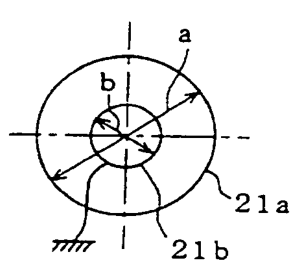
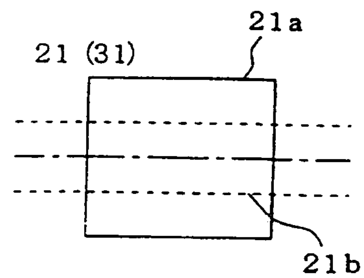
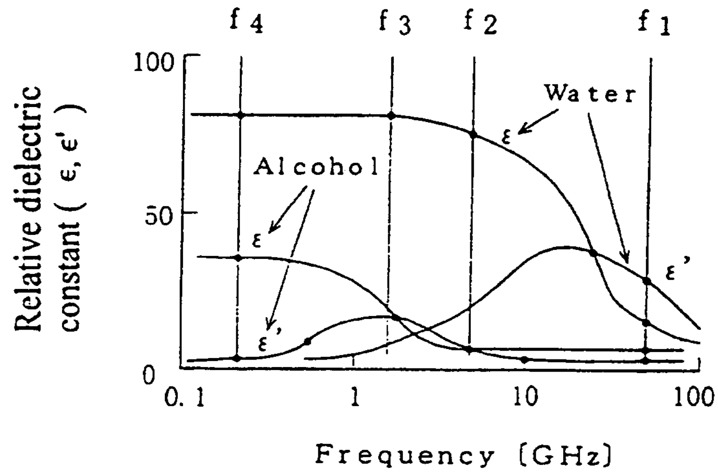


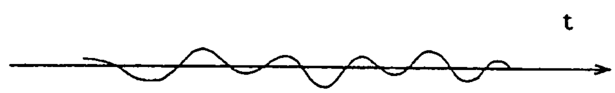
FIG. 2B



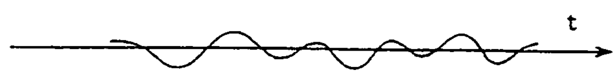
F I G. 3



F I G. 4 A



F I G. 4 B



F I G. 5

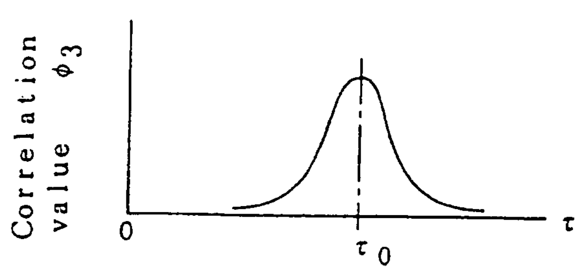
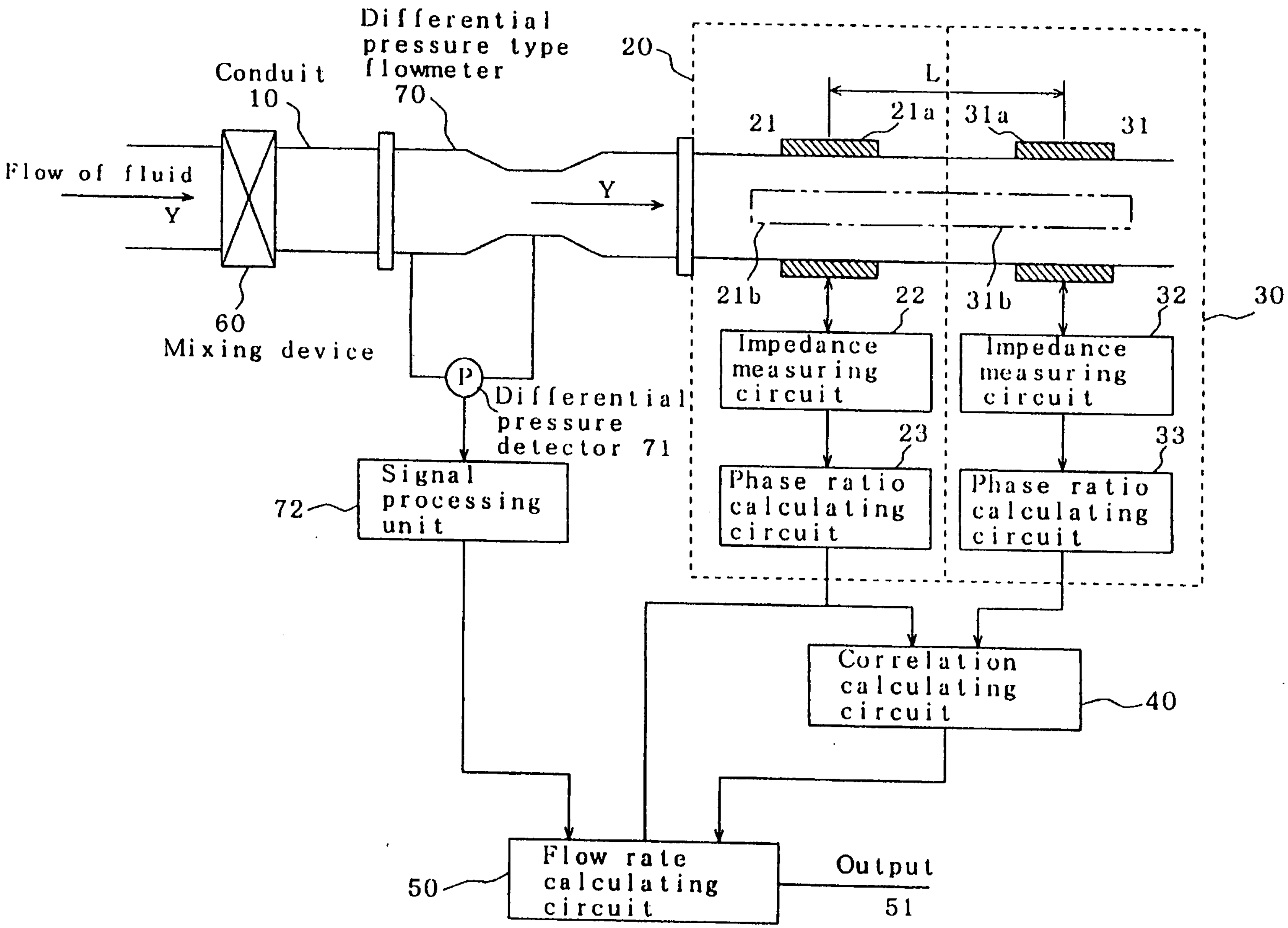


FIG. 6



Flow of fluid
Y
Conduit
10
60
Mixing device
Differential
pressure type
flowmeter
70
Y
P
Differential
pressure
detector 71
Signal
processing
unit
72
20
L
21
21a
31a
31
21b
31b
22
32
30
Impedance
measuring
circuit
Impedance
measuring
circuit
23
33
Phase ratio
calculating
circuit
Phase ratio
calculating
circuit
Correlation
calculating
circuit
40
Flow rate
calculating
circuit
50
Output
51

FIG. 7A

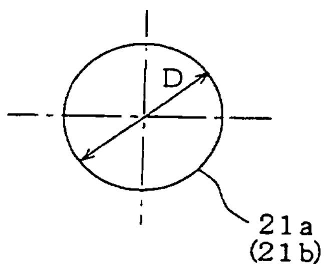
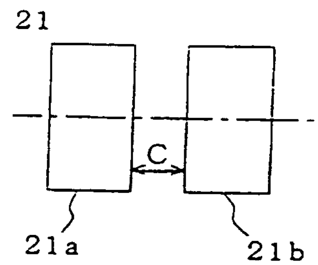


FIG. 7B



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MULTIPHASE FLOWMETER

The invention relates to a multiphase flowmeter which measures flow rates of respective fluids in a multiphase fluid in which a plurality of fluids is mixed.

Flowmeters for multiphase flow are known, which measure flow rates of respective fluids mixed in a multiphase fluid, when the multiphase fluid including, e.g. water, oil and gas flows in a multiphase flow manner in a conduit. However, such a flowmeter for multiphase flow is constructed by, e.g. a combination of a flowmeter for obtaining a total flow rate or an average flow velocity of the multiphase fluid and a large-scale device such as a Υ-ray densitometer. In this conventional device, the flow rates of the respective fluids in the multiphase fluid are obtained by calculation on the assumption that the flow velocities of the respective fluids are equal. But, the flow velocities of the respective fluids are not equal in practice, which causes errors, and then the obtained flow rates of the

respective fluids are insufficiently accurate depending on the phase ratios of the respective fluids.

The invention has been made in order to eliminate the above-mentioned problems existing in the conventional device. It is, therefore, an object of the invention to provide a flowmeter for multiphase flow, which is relatively simple in construction, and is capable of measuring flow rates of respective fluids in a multiphase fluid with high accuracy.

There is provided, in accordance with a first aspect of the invention, a flowmeter for multiphase flow, comprising: two sets of multiphase density meters each comprised of an impedance measuring circuit for applying a voltage, which is variable in frequency, between double cylinder electrodes attached to an outside and an inside of a conduit through which a multiphase fluid to be measured flows, and measuring a variation of a capacitance between the electrodes, which changes according to a relative dielectric constant of the multiphase fluid, and a phase ratio calculating circuit for receiving an output of the impedence measuring circuit to calculate phase ratios of respective fluiss mixed in the multiphase fluid; a correlation calculating circuit for receiving output signals of the phase ratios each having a fluctuation due to a flow of the multiphase fluid from the two sets of the multiphase density meters,

and obtaining a delay time corresponding to a maximul value of a cross-correlation function between the respect output signal from the two sets of multiphase density meters, to thereby obtain flow velocities of the respective fluids mixed in the multiphase fluid; and a flow rate calculating circuit for obtaining flow rates of the respect fluids based on the flow velocities obtained by the correlation calculating circuit.

According to the first aspect of the invention, phase ratios of the respective fluids are obtained based on the relative dielectric constant of the multiphase fluid depending on the frequency, and the time during which the fluid flows between two points is obtained by the cross-correlation method. Thus, not only the flow velocities but also the flow rates of the respective fluids are obtained. Accordingly, it is not necessay to use a large-scale device (such as a γ-ray densitometer in the conventional device), thereby making the construction relatively simple.

In a second aspect of the present invention, there is provided a flowmeter for multiphase flow, comprising: two sets of multiphase density meters each comprised of an impedance measuring circuit for applying a voltage, which is variable in frequency, between a pair of annular ring electrodes attached in parallel with each other to an outside of a conduit through which a multiphase fluid

to be measured flows, and measuring a variation of a capacitance between the electrodes, which changes according to a relative dielectric constant of the multiphase fluid, and a phase ratio calculating circuit for receiving an output of the impedence measuring circuit to calculate phase ratios of respective fluiss mixed in the multiphase fluid; a correlation calculating circuit for receiving output signals of the phase ratios each having a fluctuation due to a flow of the multiphase fluid from the two sets of the multiphase density meters, and obtaining a delay time corresponding to a maximul value of a cross-correlation function between the respect output signal from the two sets of multiphase density meters, to thereby obtain flow velocities of the respective fluids mixed in the multiphase fluid; and a flow rate calculating circuit for obtaining flow rates of the respect fluids based on the flow velocities obtained by the correlation calculating circuit.

Further, since the detecting electrode is constructed by the double cylinder electrodes of the parallel annular ring electrodes, there is an advantage that a flowmeter for

multiphase flow which is capable of measuring the flow rates of respective fluids in high accuracy is obtained.

Further objects and advantages of the invention will be apparent from the following description of the preferred embodiments of the invention as illustrated in the accompanying drawings.

Brief Description of the Drawings

Fig. 1 is a general arrangement showing a flowmeter for multiphase flow according to a first embodiment of the invention;

Fig. 2A is a schematic sectional view of electrodes used in the flowmeter in Fig. 1;

Fig. 2B is a side view of the electrodes in Fig. 2A;

Fig. 3 is a view showing a frequency characteristic of a relative dielectric constant of dielectric substance;

Figs. 4A and 4B each is a view showing a flow of a multiphase fluid for explaining the principle of a correlation type flowmeter;

Fig. 5 is a view showing a cross-correlation curve for explaining the principle of the correlation type flowmeter;

Fig. 6 is a general arrangement showing a flowmeter for multiphase flow according to a second embodiment of the invention;

Fig. 7A is a schematic sectional view of electrodes used in the flowmeter in Fig. 6; and

Fig. 7B is a side view of the electrodes in Fig. 7A.

In Fig. 1, reference numeral 10 designates a conduit, through which a multiphase fluid to be measured, in which a plurality of fluids such as water, oil and gas (air) is mixed, flows in the Y direction. Reference numerals 20 and 30 each designate a multiphase density meter, 40 is a correlation calculating circuit for receiving output signals from the multiphase density meters 20 and 30, respectively, and calculating a cross-correlation between both the signals to thereby obtain flow velocities of respective fluids, and 50 is a flow rate calculating circuit for receiving an output signal of the correlation calculating circuit 40 and then converting a flow velocity to a flow rate.

In the multiphase density meter 20, reference numeral 21 designates electrodes having a double cylinder electrode construction comprised of a cylindrical outer electrode 21a attached to an outer wall of the conduit 10, and a cylindrical inner electrode 21b fixedly arranged on an inner centre portion of the conduit 10 so as to be

opposed to the outer electrode 21a. The electrodes 21 are shown schematically in Fig. 2A and Fig. 2B. Fig. 2A is a sectional view of the electrodes, and Fig. 2B is a side view of the electrodes. The inner electrode 21b is earthed.

Reference numeral 22 designates an impedance measuring circuit having a function of changing the frequency, which is connected to the outer electrode 21a, and 23 is a phase ratio calculating circuit for calculating phase ratios of the respective fluids of the multiphase fluid to be measured, of which an input terminal is connected to the impedance measuring circuit 22, and an output terminal is connected to one input terminal 40a of the correlation calculating circuit 40.

The multiphase density meter 30 is identical in construction and arrangement to the multiphase density meter 20, and is comprised of electrodes 31 attached to the conduit 10 spaced from the electrodes 21 of the multiphase density meter 20 by a predetermined distance L, an impedance measuring circuit 32 and a phase ratio calculating circuit 33. An output terminal of the phase ratio calculating circuit 33 is connected to the other input terminal 40b of the correlation calculating circuit 40.

The electrodes 31 have a double cylinder construction, which, similar to the electrodes 21, comprise outer electrode 31a, and a cylindrical inner electrode 31b fixedly arranged on an inner centre portion of the conduit 10 so as to be opposed to the outer electrode 31a. The inner electrode 31b is earthed. Moreover, the inner electrode 31b of the multiphase density meter 30 and the inner electrode 21b of the multiphase density meter 20 are connected to form one body. However, the inner electrode 21b and the inner electrode 31b may be arranged separately.

The operation of the flowmeter, constructed as described above, will be now described.

The multiphase fluid to be measured, in which a plurality of fluids such as water, oil and gas are mixed, flows in the Y direction in the conduit 10 through the respective electrodes 21 and 31 of the multiphase density meters 20 and 30 (i.e. flows in the conduit 10 through both the inside and the outside of the inner electrodes 21b and 31b). In the multiphase density meter 20, a high frequency sinusoidal voltage which is variable in frequency $f(=\omega/2\pi)$ is applied to the outer electrode 21a attached to the conduit 10, by the impedance measuring circuit 22. The impedance measuring circuit 22 measures the impedance Z which is

represented by the equation $Z=1/j\omega C$, caused according to a capacitance between the outer electrode 21a and the inner electrode 21b, by applying the high frequency voltage between the outer electrode 21a and the inner electrode 21b.

Reference symbol C designates a capacitance between the outer electrode 21a and the inner electrode 21b, which is represented by the following equation (1):

$$C=K1\cdot\epsilon m/(\log b/a) \quad \cdots\cdots\cdot \quad (1)$$

where K1 represents a constant which is determined by the dimensions (shape, size, etc.) of the electrodes 21, a is the diameter of the outer electrode 21a, and b is the diameter of the inner electrode 21b. Also, ϵm represents an average relative dielectric constant of the multiphase fluid, which is calculated by the use of the following equation (2):

$$\epsilon m=(Hw\cdot\epsilon w)+(Ho\cdot\epsilon o)+(Ha\cdot\epsilon a) \quad \cdots\cdots\cdot \quad (2)$$

where H represents a phase ratio of each fluid of the multiphase fluid, ϵ represents a relative dielectric constant, and the suffices W, O and a represent water, oil, and gas (air) respectively.

In general, the frequency characteristic of the dielectric substance is shown in Fig. 3. More specifically, Fig. 3 shows relative dielectric constants ϵ of water and alcohol (oil) (as dielectric substance) with respect to the

frequency, in which the abscissa represents the frequency [GHz], and the ordinate is ϵ. As seen from Fig 3, the relative dielectric constant ϵ of the water is generally constant at 80 in the low frequency range, but exhibits an absorption characteristic at about 100 GHz. Further, the relative dielectric constant ϵ of alcohol is generally constant at about 35 in the low frequency range, but exhibits an absorption characteristic at about 1 GHz. However, it is known that the relative dielectric constant ϵ of gas (air) is constant irrespective of the frequency, and is substantially 1.

As described above, in the high frequency range f1 to f2 (which is shown in Fig. 3 and is around 10 GHz), the relative dielectric constant ϵ of water changes dramatically, but those of alcohol and gas are relatively unchanged over this high frequency range (f1 to f2).

Accordingly, when the multiphase fluid to be measured passes through the electrodes 21 of the multiphase density meter 20 in the conduit 10, the impedance Z is measured by the impedance measuring circuit 22 while each of the frequencies f1, f2 is applied to the outer electrode 21a. The capacitance C between the electrode 21a and the electrode 21b at the respective frequencies is thereby obtained. On this occasion, the relation

between the frequencies f1, f2 and the variation ΔC of the capacitance C at the respective frequencies is represented by the use of the following equation (3):

$$\Delta C=K\{\epsilon m(f1)-\epsilon m(f2)\} \quad \cdots\cdots\cdots (3)$$

When the frequency is changed from f1 to f2, $Ho\cdot\epsilon o$ and $Ha\cdot\epsilon a$ in the equation (2) are not changed, and only $Hw\cdot\epsilon w$ thereof is changed. Therefore, when the frequency is changed from f1 to f2, the variation of the relative dielectric constant ϵm in the equation (2) is caused by the change of the relative dielectric constant of the water. Then, the equation (3) is represented by the use of the following equation (4):

$$\Delta C=K\{\epsilon w(f1)-\epsilon w(f2)\}Hw \quad \cdots\cdots\cdots (4)$$

Therefore, the phase ratio Hw of the water in the multiphase fluid flowing in the conduit 10 can be obtained by applying an output of the impedance measuring circuit 22 corresponding to the impedance Z measured at the respective frequencies f1 and f2, to the phase ratio calculating circuit 23.

In a similar manner, the phase ratio Ho of the alcohol can be obtained based on the variation of the capacitance C obtained from the measured impedance Z, caused by changing the frequency applied to the outer electrode 21a from f3 to f4 (which is around 1GHz, as seen in Fig.3). The phase ratio of the

multiphase fluid as a whole flowing through the conduit 10 is represented by the use of the equation (5)

$$1=Hw+Ho+Ha \qquad \cdots\cdots\cdots (5)$$

As described above, since the phase ratio Hw of the water and the phase ratio Ho of the alcohol can be obtained according to the frequency, the phase ratio Ha of the air (which as set out above has a generally constant relative dielectric constant over the frequency range) can be obtained by the use of the equation (5).

Then, when the average density of the multiphase fluid is assumed to be ρm, ρm is represented by the use of the equation (6):

$$\rho m=Hw\cdot\rho w+Ho\cdot\rho o+ Ha\cdot\rho a \qquad \cdots\cdots\cdots (6)$$

Since the densities ρw, ρo, ρa respectively of the water, the oil and the gas are already known, the phase ratio calculating circuit 23 obtains phase density ratios Hw·ρw, Ho·ρo, Ha·ρa including the densities ρw, ρo, ρa of the respective fluids represented in the equation (6), and hence transmits output signals, i.e. signals corresponding to the phase density ratios of the respective fluids to one input terminal 40a of the correlation calculating circuit 40.

The multiphase fluid to be measured flows along the electrodes 31 of the multiphase density meter 30, which electrodes 31 are separated from the electrodes 21 by the distance L. As a result, the signals corresponding to the respective phase

density ratios $Hw \cdot \rho w$, $Ho \cdot \rho o$, $Ha \cdot \rho a$ of the multiphase fluid are also obtained by the phase ratio calculating circuit 33 of the multiphase density meter 30 similarly to the multiphase density meter 20. Then, these signals are applied to the other input terminal 40b of the correlation calculating circuit 40.

The operation of the correlation calculating circuit 40 will be described below.

Generally, the multiphase fluid to be measured flows in the conduit 10 with an irregular fluctuation (e.g. of the density ρm of the multiphase fluid) as shown in Figs. 4A and 4B. In Figs. 4A and 4B, reference symbol t represents time. On this occasion, the multiphase fluid with the fluctuation as shown in Fig. 4A, having passed through the electrodes 21 in the multiphase density meter 20 passes through the electrodes 31 in the multiphase density meter 30. The electrodes 31 are arranged downstream of the electrodes 21 and are spaced from the electrodes 21 by a constant distance L, with the substantially unchanged fluctuation as shown in Fig. 4B.

Then, if the time during which the multiphase fluid to be measured moves from the electrodes 21 to the electrodes 31 is assumed to be τo seconds, a signal having a certain fluctuation is obtained from the phase ratio

calculating circuit 33 of the multiphase density meter 30 τo seconds after the same signal was obtained from the phase ratio calculating circuit 23 of the multiphase density meter 20.

The correlation calculating circuit 40 first obtains the flow velocity of the water based on the signals corresponding to the phase density ratio $Hw \cdot \rho w$ of the water obtained by the multiphase density meters 20, 30. When a signal,obtained from the phase ratio calculating circuit 23 of the multiphase density meter 20 and applied to the correlation calculating circuit 40,is assumed to be Sw23, the same signal is obtained after a lapse of τo seconds from the phase ratio calculating circuit 33 of the multiphase density meter 30 as shown in the following equation (7):

$$Sw33(t)=Sw23(t-\tau o) \qquad \cdots\cdots\cdots (7)$$

where Sw33 is a signal obtained from the phase ratio calculating circuit 33.

Then, if the cross-correlation function between the upstream side signal Sw23 and the downstream side signal Sw33 is assumed to be $\Phi 3w$, $\Phi 3w$ is represented by the use of the following equation (8) based on the definition of the well known cross-correlation function:

$$\Phi 3w=(1/T)\int_0^T Sw23(t)\cdot Sw33(t+\tau)dt \qquad \cdots\cdots\cdots (8)$$

where T represents an integration time. The curve of the cross-correlation function $\Phi 3w$ is represented by the cross-correlation curve having a maximal value when $\tau=\tau o$ as shown in Fig. 5. There is known a manner of obtaining the maximal value τo, based on the cross-correlation curve shown in Fig. 5, by obtaining the differentiated value of the cross-correlation function $\Phi 3w$. The calculation for obtaining the maximal value τo in this manner is carried out by the correlation calculating circuit 40.

Further, the flow velocity Vw of the water is obtained by the use of the following equation (9) based on the value τo obtained as above:

$$Vw=L/\tau o\,(m/s) \qquad \cdots\cdots\cdot (9)$$

In a similar manner, cross-correlation functions $\Phi 3$ for the oil and the gas can be respectively obtained based on the phase density ratio $Ho\cdot\rho o$ of the alcohol and the phase density ratio $Ha\cdot\rho a$ of the gas obtained by the multiphase density meters 20 and 30. Thus the values τo at which the cross-correlation function $\Phi 3$ attains the maximal value, and the flow velocities Vo and Va can be obtained by the correlation calculating circuit 40. Further, the flow rate calculating circuit 50 calculates the flow rate of every fluid by multiplying the flow

velocity by the phase ratio for each of the respective fluids.

Fig. 6 is a general arrangement showing a flowmeter for multiphase flow according to a second exemplary embodiment of the invention. In Fig. 6, the multiphase density meters 20, 30 and the correlation calculating circuit 40 are identical in construction and arrangement with the first embodiment.

In Fig. 6, reference numeral 10 designates the above-mentioned fluid conduit through which the multiphase fluid to be measured, in which a plurality of fluids such as water, oil and gas (air) is mixed, flows as mentioned above. Reference numeral 60 designates a mixing device disposed in the conduit 10 at a location upstream of the multiphase density meters 20 and 30, which homogenizes the multiphase fluid flowing through the conduit 10. Reference numeral 70 is a publicly available differential pressure type flowmeter disposed in the conduit 10 between the mixing device 60 and the multiphase density meter 20, which comprises a differential pressure detector 71 and a signal processing circuit 72 for carrying out the calculation on the output signal of the differential pressure detector 71. Reference numeral 50 designates a flow rate calculating circuit, to which respective output

terminals of the signal processing circuit 72 of the differential pressure type flowmeter 70, the phase ratio calculating circuit 23 constituting the multiphase density meter 20, and the correlation calculating circuit 40 are connected.

In the first embodiment, the flow velocities of the respective fluids are obtained by obtaining the phase density ratios of the respective fluids of the multiphase fluid based on the change of the relative dielectric constant ϵm of the multiphase fluid to be measured, according to the change of the frequency and then obtaining the cross-correlation of the signals corresponding to the ratios. However, there is a case, particularly in some kinds of oil, when the relative dielectric constant ϵ does not necessarily change clearly with the change of frequency. The device of Fig. 6 is preferred in such a case.

That is, a differential pressure ΔP detected by the differential pressure type flowmeter 70 is represented by the use of the following equation (10):

$$\Delta P=\Delta Pw+\Delta Po+\Delta Pa$$

$$=Kpw \cdot Hw \cdot \rho w \cdot Vw^2+Kpo \cdot Ho \cdot \rho o \cdot Vo^2+ Kpa \cdot Ha \cdot \rho a \cdot Va^2 \quad \cdots\cdots\cdots (10)$$

where Kp represents a constant and V represents a flow velocity. If average flow velocity of the fluid which is homogenized in flow by the mixing device 60 is assumed to be Vm, the flow velocities the respective fluids are equal to Vm (Vm=Vw=Vo=Va). The average flow velocity Vm is determined by obtaining the cross-correlation of the multiphase fluid to be measured, by means of the multiphase density meters 20, 30 and the correlation calculating circuit 40 as shown by the equation (9).

Then, if the density of the air is neglected since its value is small, the differential pressure ΔP is represented by the use of the following equation (11):

$$\Delta P = Kpw \cdot Hw \cdot \rho w \cdot Vw^2 + Kpo \cdot Ho \cdot \rho o \cdot Vo^2 \quad \cdots\cdots \quad (11)$$

The phase ratio Hw of the water is obtained by the phase ratio calculating circuit 23 of the multiphase density meter 20. If Hw is determined, the phase ratio Ho of the oil can be determined by means of the equation (11). When Hw and Ho are determined, the phase ratio Ha can be determined by means of the equation (5). Then, the flow rates of the respective fluids are obtained by the flow rate calculating circuit 50 by the use of the following equation (12) based on the phase ratios H of the respective fluids:

$$Q = Kv \cdot H \cdot V \qquad \cdots\cdots\cdots (12)$$

where Kv represents the cross-sectional area of the conduit.

Moreover, in the above-mentioned embodiments, the impedance Z is measured using the real part ϵ of the relative dielectric constant and the variation of ϵ is determined. However, the impedance Z may be measured by the use of the variation of the imaginary part of the relative dielectric constant. The frequency characteristic of the imaginary part of the relative dielectric constant is represented by reference numeral ϵ' in Fig. 3.

Also, the above description is made for the case where the electrodes 21 have a double cylinder electrode construction comprised of the outer electrode 21a and the inner electrode 21b, but any other construction may be employed. For example, as shown in Fig. 7A and Fig. 7B, a parallel annular ring construction may be employed in which a pair of annular ring electrodes 21a and 21b as the electrodes 21 are attached to an outside of the conduit 10 spaced from each other. On this occasion, the similar parallel annular ring electrodes are employed for the electrodes 31 also, and both the annular ring electrodes 21 and 31 are attached to the conduit 10 and spaced from each other by the distance L as shown in Fig. 1 and Fig. 6. In both the electrodes 21, 31, the

electrode 21a is connected to the impedance measuring circuit 22, and then the electrode 21b is earthed, while the electrode 31a is connected to the impedance measuring circuit 32, and then the electrode 31b is earthed. Moreover, Fig. 7A is a sectional view of parallel annular ring electrodes 21 (31), and Fig. 7B is a side view of the electrodes in Fig. 7A.

In the above construction of the parallel annular ring electrodes 21, when a high frequency voltage is applied to the electrode 21a by the impedance measuring circuit 22, lines of electric force pass between the electrodes 21a and 21b, and therefore an impedance represented by the equation $Z=1/j\omega C$ is caused, due to the capacitance between both the electrodes 21a, 21b, where C represents a capacitance between the electrodes 21a, 21b, which is represented by the use of the following equation (13):

$$C=K2 \cdot \epsilon m \cdot D \qquad \cdots\cdots\cdots (13)$$

where K2 represents a constant due to the dimensions (shape,size,etc.) of the electrode 21a, 21b, D is a diameter of the electrode 21a, 21b, as shown in Fig. 7A, and ϵm is an average relative dielectric constant similar to that of the equation (2).

The electrodes 21, 31 can be constructed by using a pair of "electrode pieces" opposed to each other. However, as compared with the electrodes comprising the above "pieces", the double cylinder electrodes or the parallel annular ring electrodes used in the invention can ensure largely the area between the opposed electrodes, so that the flow rates of the multiphase fluid can be detected in high accuracy as compared with "the electrode pieces".

Many widely different embodiments of the invention may be constructed without departing from the scope of the invention. It should be understood that the invention is not limited to the specific embodiments described in the specification, except as defined in the appended claims.

CLAIMS

1. A multiphase flowmeter comprising:

a plurality of multiphase density meters each comprising: an impedance measuring circuit for applying a voltage of variable frequency between double cylinder electrodes located on an outside and inside respectively of a conduit, the conduit arranged to receive a flow of a multiphase fluid, and the impedance measuring circuit further being arranged to measure a variation in the capacitance between the electrodes, which change in capacitance is dependent upon a relative dielectric constant of the multiphase fluid; and a phase ratio calculating circuit for receiving an output of said impedance measuring circuit to calculate phase ratios of respective fluids mixed in the multiphase fluid;

a correlation calculating circuit for receiving output signals from the plurality of multiphase density meters, the output signals being representative of the phase ratios which each have a fluctuation due to a flow of said multiphase fluid, and for obtaining a delay time corresponding to the maximal value of a cross-correlation function between said respective output signals from the plurality of multiphase density meters, to thereby obtain flow velocities of the respective fluids mixed in the multiphase fluid; and

a flow rate calculating circuit for obtaining flow rates of the respective fluids based on the flow velocities obtained by the correlation calculating circuit.

2. A multiphase flowmeter as claimed in claim 1, further comprising a mixing device for homogenizing the multiphase fluid to be measured, the mixing device being in the conduit up-stream of the double cylinder electrode, and a differential pressure type flowmeter for detecting a flow rate of the multiphase fluid passing through the mixing device, the flow rate calculating circuit receiving an output of the differential pressure type flowmeter, an output of the phase ratio calculating circuit, the multiphase density meter including said phase ratio calculating circuit, and an output of the correlation calculating circuit, to thereby obtain flow rates of the respective fluids mixed in the multiphase fluid.

3. A multiphase flowmeter as claimed in claim 1, in which the impedance is measured by the use of a real part of the relative dielectric constant of the multiphase fluid.

4. A multiphase flowmeter as claimed in claim 1, in

which the impedance is measured by the use of an imaginary part of the relative dielectric constant of the multiphase fluid.

5. A multiphase flowmeter comprising:

a plurality of multiphase density meters each comprising: an impedance measuring circuit for applying a voltage of variable frequency between a pair of annular ring electrodes attached in parallel with each other to an outside of a conduit, the conduit arranged to receive a flow of a multiphase fluid, and the impedance measuring circuit further being arranged to measure a variation in the capacitance between the electrodes, which change in capacitance is dependent upon a relative dielectric constant of the multiphase fluid; and a phase ratio calculating circuit for receiving an output of said impedance measuring circuit to calculate phase ratios of respective fluids mixed in the multiphase fluid;

a correlation calculating circuit for receiving output signals from the plurality of multiphase density meters, the output signals being representative of the phase ratios which each have a fluctuation due to a flow of said multiphase fluid, and for obtaining a delay time corresponding to the maximal value of a cross-correlation function between said respective output signals from the plurality of multiphase density meters, to thereby obtain

flow velocities of the respective fluids mixed in the multiphase fluid; and

a flow rate calculating circuit for obtaining flow rates of the respective fluids based on the flow velocities obtained by the correlation calculating circuit.

6. A multiphase flowmeter as claimed in claim 5, further comprising a mixing device for homogenizing the multiphase fluid to be measured, the mixing device being in the conduit up-stream of the parallel annular ring electrodes, and a differential pressure type flowmeter for detecting a flow rate of the multiphase fluid passing through the mixing device, the flow rate calculating circuit receiving an output of the differential pressure type flowmeter, an output of the phase ratio calculating circuit, the multiphase density meter including said phase ratio calculating circuit, and an output of the correlation calculating circuit, to thereby obtain flow rates of the respective fluids mixed in the multiphase fluid.

7. A multiphase flowmeter as claimed in claim 5, in which the impedance is measured by the use of a real part of the relative dielectric constant of the multiphase fluid.

8. A multiphase flowmeter as claimed in claim 5, in which the impedance is measured by the use of imaginary part of the relative dielectric constant of the multiphase fluid.

9. A multiphase flowmeter constructed and arranged substantially as specifically described with reference to and as shown in Figs. 1 to 5, optionally modified as shown in Fig. 6.

The Patent Office

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Claims searched:	1 to 9	**Date of search:**	26 August 1997

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G1N NCVT

Int Cl (Ed.6): G01F

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	EP0510774A2	(SHELL)	
A	US5396806	(AUBURN)	
A	US4899101	(US DEPT. OF ENERGY)	

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